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THESIS

THE EFFECT OF REFERENCE SIGNALS IN A VISUAL VIGILANCE TASK

by

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The Effect of Reference Signals in a Visual Vigilance Task

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ABSTRACT

The effect of reference signals on performance in a visual vigilance task was studied under three conditions. Reference signals were presented on the same display as the real signals. In condition 1 (control), no reference signals were displayed. Subjects could demand reference signals whenever they wished in condition 2 (demand reference). Reference signals were programmed at arbitrary times during the experiment in condition 3 (programmed reference). Twenty-four subjects were used, eight in each condition. Neither the display of reference signals upon demand nor the programmed display of reference signals significantly affected the overall level of performance. However, after activation of the reference signal sequence in condition 2 (demand reference), there was a significant short-term improvement in performance. No significant change in the rate of commissive errors was found. All three groups showed a significant deterioration of performance over time during the experiment.

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I. INTRODUCTION

The classical vigilance task, which stems from radar operator performance in World War II, has been questioned by some researchers. The weak, brief duration signals of the typical laboratory study purportedly are rarely encountered in contemporary monitoring tasks [Kibler 1965]. The human operator is required to monitor multiple information sources, or displays. Frequently he must detect more than one target and determine an appropriate response.

Technological changes have undoubtedly complicated the monitoring problem. If monitoring is defined to encompass both observation and processing of information, then the relationship between classical vigilance experiments and the modern monitoring situation is indeed questionable. Perhaps this contradiction is more apparent than real. Recent studies seem to have failed to demonstrate the relevance of their findings to applied tasks. Such demonstration might properly be made by field tests of experimental results, but this can be quite expensive.

Certain restricted applications may be proposed to establish the relationship of laboratory studies to applied tasks. The two aspects of monitoring, that is, observing and processing, may be separated in many applied tasks. A field artillery counter-mortar radar operator must first detect a brief signal. After the signal is detected, appropriate action can be taken. The detection of the

target thus is separated from processing and interpreting the target information. Although the monitoring problem is highly complicated for many tasks, in some cases the task may be divided into subtasks which do parallel classical laboratory experiments.

In recent years, numerous efforts have been made to improve performance in vigilance tasks. Early experience in the field resulted in the use of frequent rest periods to maintain a higher level of performance. This approach has been validated by Mackworth [1948]. Some approaches have emphasized training [Aiken and Lau 1967, Wiener 1968, Wiener and Attwood 1968], while others have attempted to raise the performance level directly. The latter category may be divided into two groups: studies of the effect of signal rate on performance and studies involving external stimulation of the subject.

The percentage of detections increases as signal rate increases [Jenkins 1958]. This relationship has been used to maintain higher performance by the introduction of "artificial" signals indistinguishable from "real" signals into the vigilance task [Baker 1960, Lawson 1959]. This result is contested by Wilkinson [1964], who insists the presence of artificial signals is effective only if their detection is rewarded. The introduction of signals which are discriminably different from the wanted, or real, signal has produced inconclusive results [Wilkinson 1964].

The preponderance of the studies seems to support the use of artificial signals as an aid to improve detection performance. The introduction of a large number of artificial signals is not always practicable in an applied task and one inherent problem is the possibility of obscuring a real signal by an artificial one.

An hypothesis which could conceivably lead to the conclusion that the introduction of artificial signals would improve performance is the "criterion-shift" hypothesis. It states that, given a monitoring situation in which discrimination must be made between signal and non-signal (noise) stimuli with respect to some dimension, the threshold, or magnitude, of the dimension which is defined as a signal shifts to higher values over time [Baker and O'Hanlon 1963a]. Frequent reinforcement of the threshold would tend to negate or attenuate the criterion shift.

It has been suggested that if a reference signal, identical to the real signal, were displayed during a vigilance task, the criterion-shift hypothesis could be tested. Baker and O'Hanlon [1963a, 1963b] used a reference signal displayed adjacent to the main display to test the hypothesis. The task used was the detection of a change in the brightness of a light. They concluded that the general level of target detection performance was not aided by the adjacent display. Presenting a reference signal on a display separate from the main display requires the subject to monitor two displays. In this manner, the reference

signals could not directly obscure a real signal, but a division of effort was required. Baker and O'Hanlon further complicated the task by embedding the reference signal in a sequence of normal signals, and the subject had to detect which were the reference signals.

To eliminate the division of effort problem, this experiment was designed to present the reference signal on the same display as the real signal, and also to cue the subject as to which was the reference signal. Under these conditions, the reference signal could interfere with the detection of a real signal; however, the anticipated number of reference and real signals was small and the danger was considered to be minimal for a practical situation. For this experiment, a restriction prohibiting interference between reference and real real signals was imposed.

II. METHOD

The task used to obtain a vigilance decrement was an adaptation of that used by Jenkins [1958], and since used by others [Wiener 1968], in which a voltmeter needle made a normal rightward deflection of 31 degrees from its resting position at a rate of 60 deflections per minute. The signal was a deflection of 35 degrees from the resting position.

A. DESIGN

The signal schedule consisted of 64 signals appearing at random intervals, with the restrictions that the minimum inter-signal interval was 18 seconds, and 16 signals appeared in each 24 minute period. The test was 96 minutes long.

The effect of time on vigilance level was measured under three conditions. In condition 1, subjects were required to detect signals with no aids or assistance. Condition 2, demand reference, permitted the subjects to request that a reference signal be displayed on the meter. They could make as many or as few requests as they desired, and at any time during the test. In condition 3, programmed reference, reference signals were presented on the display during the test. For the purposes of this test, reference signals were arbitrarily programmed in the same time period in which the preponderance of the requests were made in condition 2, with the restriction that the reference signal

sequence would not occur within two seconds of a real signal. The number of programmed reference signals was determined by taking the average number of requested reference signals from condition 2.

The reference signal sequence for conditions 2 and 3 was as follows: The red pilot light blinked twice with a one-second interval between blinks, followed by another one-second delay, then was lit for three seconds. The first deflection after the light was extinguished was a signal, followed by alternate normal and signal deflections until three signals had been presented.

B. SUBJECTS

Twenty-four male subjects ranging from 18 to 36 years of age were used in the experiment. Of the group, 23 were U.S. Navy enlisted men, and one was a U.S. Army officer. Those who habitually wore glasses were required to wear them during the experiment. Eight subjects were randomly assigned to each of the three conditions.

C. APPARATUS

The apparatus consisted of (1) the display, (2) controlling and recording equipment and (3) the signal generating equipment.

Each of three booths was equipped with a voltmeter with the face painted a flat white and the needle black. The subject was provided a button-type switch which he pressed when he detected a signal. A switch mounted on the table

was used to request a reference signal (condition 2), and a red pilot light mounted two inches below the voltmeter alerted the subject that the reference signal sequence in conditions 2 and 3 was to be presented. White background noise was provided through earphones for each subject.

The experimenter controlled the demand reference signal by a switching system which allowed him to present the entire reference signal sequence. This sequence could be presented to only one booth at a time. The table mounted switch in the booth turned on a light at the experimenter's console, alerting him to initiate the reference signal sequence.

A six-channel event recorder (Lafayette multi-pen time recorder, model 5041) was used to record the signals presented to the subjects and their responses. A detection was considered to be a response within two seconds after the presentation of a signal. Any other response was a commissive error (false alarm). All responses proved to be almost instantaneous or separated from the signal by several seconds, so this restriction was never invoked.

The defelections of the meter needle were controlled by a punched paper tape read by an Ohr-Tronics paper tape reader, model 166. In conditions 1 and 2, only the normal and signal deflections were programmed on the tape. In condition 3, the reference signal sequence was also controlled by the tape.

D. PROCEDURE

Subjects were given standard instructions (Appendixes A, B and C) which differed only with regard to reference signals. Subjects in one group were not aware of the conditions under which the other groups performed. A two-minute demonstration and training session was repeated until results indicated that the subjects understood the instructions. Each subject performed one 96-minute vigil.

III. RESULTS

The results were examined in three categories. The number of detections was analyzed to determine if any one technique provided greater detectability of the signal. Commissive errors were looked at to evaluate the possibility of a reduction in false alarms. Finally, possible temporal effects grouped around the reference signals were examined.

A. DETECTIONS

Figure 1 shows performance in terms of percentage of signals detected in each 24-minute period. Performance

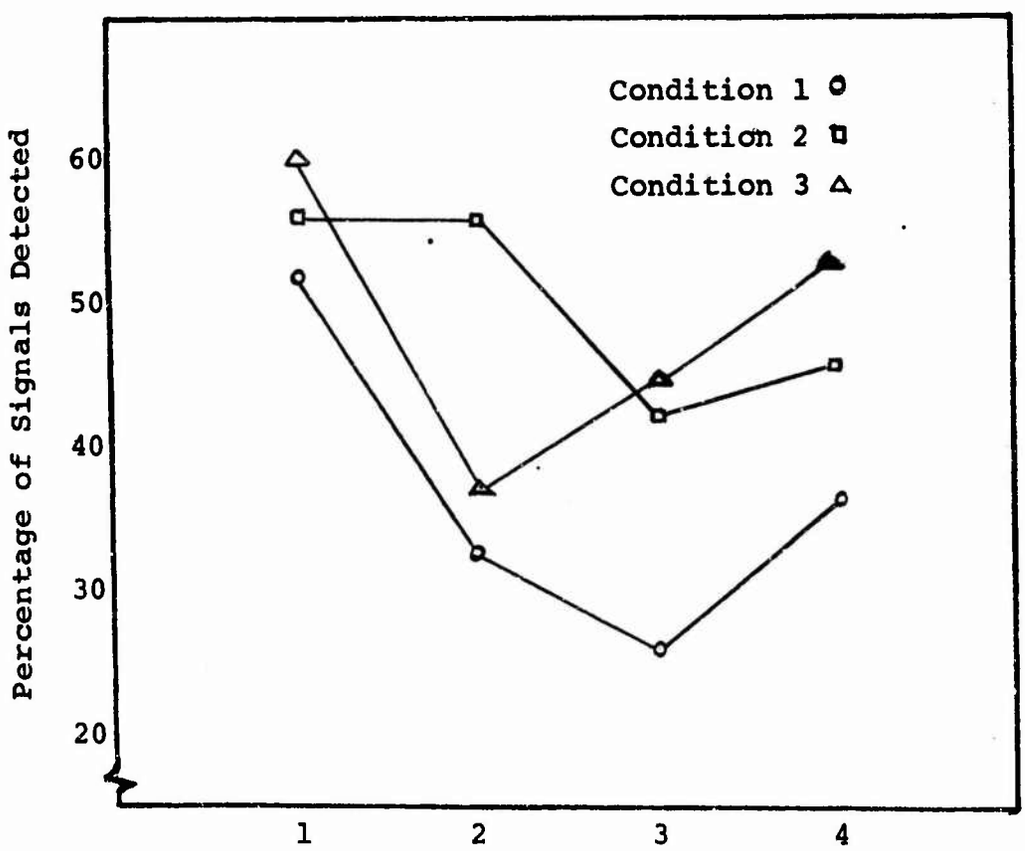

Figure 1. Percentage of Signals Detected Per 24-Minute Period

progressively declined throughout the test. The rate of decline under the demand reference and programmed reference conditions seemed to be less than under the control condition.

The data were analyzed by a nested analysis of variance in which subjects were nested in each of the three conditions, but common to all four time periods. The data were first transformed by an arcsine transformation [Winer 1962]. The analysis is shown in Table I.

TABLE I

ANALYSIS OF VARIANCE OF SIGNALS DETECTED DURING TEST

Source	df	MS	F	p
Between subjects	23			
Conditions	2	2.095	1.141	N.S.
Error (bet.)	21	1.836		
Within subjects	72			
Periods	3	0.721	4.685	.01
Periods x Conditions	6	0.310	2.016	N.S.
Error (with.)	63	0.154		
Total	95			

From Table I, it is apparent that s significant decline in performance occurred during the test, but the difference between conditions was not significant. The periods x conditions interaction was not significant.

B. COMMISSIVE ERRORS

The total number of commissive errors for each subject was computed and the median of these for the three groups was found to be seven. The individual subject totals were cast into a contingency table with conditions as one dimension and the frequency of subjects above and below the median as the other dimension. These data are shown in Table II.

TABLE II

COMMISSIVE ERROR DATA

	Group 1	Group 2	Group
Above	4	4	3
Below	4	4	5

The low frequency in each category prevented the use of the median test. However, none of the data arouses any suspicion of difference in the false alarm rate because of the different conditions.

C. EFFECT OF REFERENCE DISPLAY ON SUBSEQUENT PERFORMANCE

The data for conditions 2 and 3 were examined to determine if the activation of the reference display affected subsequent detections. Table III shows the percentages of detections of the last signal prior to activation of the

reference signal sequence and the first signal after the reference signal sequence terminated. The probability that the difference was significant was determined by the t-test. The average time from the last signal to the activation of the reference signal sequence was 57 seconds, and from the termination of the reference signal sequence to the next signal was 79 seconds.

TABLE III

SUMMARY OF DETECTIONS PRIOR TO AND FOLLOWING REFERENCE SIGNALS

Condition	Prior Signals	Signals Immediately Following	p
Demand (2)	18.2%	36.4%	.05
Programmed (3)	44.0%	44.0%	0

Table III indicates that significantly more signals were detected just after the display of the reference signal in condition 2, but there was no difference in condition 3.

D. FREQUENCY OF DEMANDS

To determine the frequency of reference signals for condition 3, all subjects in condition 2 were tested first. The average frequency of demands was 0.34 per period. The preponderance of demands occurred early in the second period and late in the third period. Consequently, one reference

signal sequence was displayed in each of the second and third periods in condition 3. Three subjects did not make a demand. Those who did make a demand were in general those who scored the fewest detections overall.

IV. DISCUSSION

Both condition 2 (demand reference) and condition 3 (programmed reference) appeared to result in more detections than condition 1. Figure 1 shows that condition 1 resulted in the poorest performance in every time period. However, the differences were not statistically significant, as shown in Table I. Overall vigilance performance was not improved by presenting reference signals on the same display with the real signals.

The results obtained by Baker and O'Hanlon [1963b] showed a significant periods x conditions interaction, and further analysis revealed that the rate of deterioration of performance was significantly lower in the experimental conditions than in the control condition. However, they did not accept the difference in deterioration rates as being a real difference because of certain peculiarities of their data. In the present experiment, no significant periods x conditions interaction was found, although such an interaction might have been suspected from the data in Figure 1.

A study of the commissive errors does not lead one to suspect that any improvement could have been made in the false alarm rate through the use of reference signals. While the sample size was too small to make a satisfactory statistical study of the data, Table II does not suggest any difference in false alarms due to the different conditions.

It was found that the reference signals in condition 2 had a short-term effect on detection performance. This partially confirms the results obtained by Baker and O'Hanlon [1963b], in which they found short-term effects in both demand reference and programmed reference conditions. However, these results cannot be blithely accepted as meaningful. In the present study, it was noted that the subjects with the poorest performance were the ones to make the demands. It cannot be concluded that if all subjects had made demands, they would have experienced a similar short-term improvement. Indeed, it is questionable if the reference signal caused the improvement, or whether it played the part of an external stimulus to improve performance [Randel 1968]. Since condition 3 did not produce a short-term improvement, it might be suspected that the demands made were merely an effort on the part of the subject to arouse his slackening interest in the task.

V. CONCLUSIONS

The general level of performance in a vigilance task of the type used in this study was not enhanced by the presentation of a reference signal on the same display with the real signal, either when demanded by the observer or when arbitrarily programmed by the experimenter.

When a reference signal was displayed upon the demand of the observer, detection performance was significantly improved for a brief period.

APPENDIX A

INSTRUCTIONS TO SUBJECTS: CONTROL GROUP

In front of you is a meter with no markings on its face. During this period, the meter needle will be deflected at about one deflection per second like this (demonstrate three normal deflections). This is called a normal signal. Occasionally, the needle will be deflected farther to the right than normal. This is a target signal, and looks like this (demonstrate one normal signal followed by one target signal). When you see the larger deflection, immediately push the button in your right hand. The button mounted on the table and the red light below the meter will not be used in this experiment.

Your job is to detect and report as many target signals as you can, but do not respond unless you actually see a target signal. The target signals will occur very infrequently and they will be brief, so you must remain alert and watch for them. You may smoke if you wish. Do not tamper with or touch the apparatus or lights.

A demonstration will now be given. Watch the meter and respond as soon as you detect the target signals. (A two-minute demonstration with ten target signals is presented.)

Remember that the target signals will occur at a much slower rate during the experiment.

Are there any questions?

We will now begin the experimental session. You will be told when the experiment is over. Remember, stay alert and watch the meter.

Are you ready?

APPENDIX B

INSTRUCTIONS TO SUBJECTS: DEMAND REFERENCE GROUP

In front of you is a meter with no markings on its face. During this period, the meter needle will be deflected at about one deflection per second, like this (demonstrate three normal deflections). This is called a normal signal. Occasionally, the needle will be deflected farther to the right than normal. This is a target signal, and looks like this (demonstrate one normal signal followed by one target signal). When you see the larger deflection, immediately push the button in your right hand.

Your job is to detect and report as many target signals as you can, but do not respond unless you actually see a target signal. The target signals will occur very infrequently and they will be brief, so you must remain alert and watch for them. You may smoke if you wish. Do not tamper with or touch the apparatus or lights.

At any time you may request a sample target signal be shown to you by pushing the button mounted on the table near your left hand. After you request the target signal, you will see the red light below the meter blink twice, then remain on for three seconds. You will then see three target signals in the following sequence - watch the meter (sample target signal sequence is demonstrated): The first signal after the light goes out will be a target signal followed by a normal signal, then another target signal, a

normal, and the third target signal. Please push the button when you see these target signals. One word of caution: You may cover up a real target signal when you request a sample target signal.

During the experiment, I can give sample target signals to only one booth at a time, so you may have to wait a few seconds after your request to get the sample signal.

A demonstration will now be given. Watch the meter and respond as soon as you detect the target signals. Please do not request a sample target signal during this demonstration. (A two-minute demonstration with ten target signals is presented.)

Remember that the target signals will occur at a much slower rate during the experiment.

Are there any questions?

We will now begin the experimental session. You are free to request a sample target signal when you wish, recalling that you run the risk of covering up a real target signal. You will be told when the experiment is over. Remember, stay alert and watch the meter.

Are you ready?

APPENDIX C

INSTRUCTIONS TO SUBJECTS: PROGRAMMED REFERENCE GROUP

In front of you is a meter with no markings on its face. During this period, the meter needle will be deflected at about one deflection per second, like this (demonstrate three normal deflections). This is called a normal signal. Occasionally, the needle will be deflected farther to the right than normal. This is a target signal, and looks like this (demonstrate one normal signal followed by one target signal). When you see the larger deflection, immediately push the button in your right hand. The button mounted on the table near your left hand will not be used in this experiment.

Your job is to detect and report as many target signals as you can, but do not respond unless you actually see a target signal. The target signals will occur very infrequently and they will be brief, so you must remain alert and watch for them. You may smoke if you wish. Do not tamper with or touch the apparatus or lights.

Occasionally during the experiment, you will be shown a sample target signal. You will see the red light below the meter blink twice, then remain on for three seconds. You will then see three target signals in the following sequences - watch the meter (sample target signal sequence is demonstrated): The first signal after the red light goes out will be a target signal followed by a normal signal,

then another target signal, a normal, and the third target signal. Please push the button when you see these target signals.

A demonstration will now be given. Watch the meter and respond as soon as you detect the target signals. (A two-minute demonstration with ten target signals and one sample target signal sequence is presented.)

Remember that the target signals will occur at a much slower rate during the experiment.

Are there any questions?

We will now begin the experimental session. You will be told when the experiment is over. Remember, stay alert and watch the meter.

Are you ready?

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13. ABSTRACT

The effect of reference signals on performance in a visual vigilance task was studied under three conditions. Reference signals were presented on the same display as the real signals. In condition 1 (control), no reference signals were displayed. Subjects could demand reference signals whenever they wished in condition 2 (demand reference). Reference signals were programmed at arbitrary times during the experiment in condition 3 (programmed reference). Twenty-four subjects were used, eight in each condition. Neither the display of reference signals upon demand nor the programmed display of reference signals significantly affected the overall level of performance. However, after activation of the reference signal sequence in condition 2 (demand reference), there was a significant short-term improvement in performance. No significant change in the rate of commissive errors was found. All three groups showed a significant deterioration of performance over time during the experiment.

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